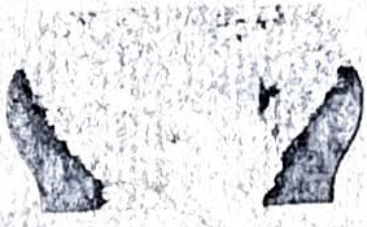
ACCIDENT ANALYSIS



The Pocket Index

THE POCKET INDEX is a reference manual designed to provide quick access to the many formulas that are used in determining speeds of vehicles that have been involved in traffic accidents.

The derivations of these formulas are included for the benefit of the 'speed expert' who may wish to make reference to them while in the courtroom. Some explanation is given of these derivations in the hope that many accident investigators will understand them and perhaps become 'speed experts'.

The INDEX is a result of fourteen years of training in mathematics, physics and accident investigation. This training has been received at San Diego City College, the University of California and the California Highway Patrol Academy. Training at the Academy included a special advanced course in determination of speeds of vehicles prior to collision.

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TABLE OF CONTENTS

ACCELERATION FORMULA.....PAGE 9
BASIC PHYSICS FORMULAS.....PAGE 7
CO-EFFICIENT OF FRICTION .....PAGE 24
CONVERSION FACTORS.....PAGE 24

DERIVATION OF FORMULAS
- ACCELERATION .....PAGE 17
- CENTRIFUGAL.....PAGE 14
- COMBINED SPEED.....PAGE 16
- FALL.....PAGE 18
- LOCKED WHEEL SKID.....PAGE 11
- RADIUS .....PAGE 8
- ROLL-OVER.....PAGE 21
- VAULT .....PAGE 21

RADIUS FORMULA.....PAGE 8
REACTION DISTANCE TABLE ...PAGE 26
SINES, COSINES & TANGENTS....PAGE 23
SPEED FORMULAS .....PAGE 9
SYMBOLS .....PAGE 6
TABLES..... PAGES 24, 25, 26, 27, 28, 29

IMPORTANT WAYS TO USE

Speed determination is an important part of accident analysis. It is possible to establish the approximate speeds of vehicles in almost every traffic accident. Some causes of the accident may not be discovered until positions of the vehicles prior to collision are known. These positions can often be established with speed determination.

Example #1. Intersection collision involving a right of way violation: speeds of the vehicles and their relationship to each other prior to entering the intersection may establish which one had the right of way.

Example #2. Vehicle entering highway from a stop street: minimum speed at a point a certain distance beyond stop sign may be in excess of the maximum possible speed attainable in that distance.

Example #3. Collision involving turning movement or vehicle crosswise in roadway: knowing approach speed of the vehicle you may be able to determine that a legal turn was impossible at that speed.

The INDEX is a reference book. An attempt to include further explanation would result in a book too large for the shirt pocket.

SYMBOLS AND FACTORS USED IN SPEED DETERMINATION

a = acceleration
C = chord
e = grade or super-elevation (in percent)
F = Force
f = co-efficient of friction (in percent)
g = gravity (32.2 feet per sec. per sec.)
h = height or change of elevation
KE = Kinetic Energy
M = Mass
m = median or middle ordinate
R = radius of circle
s = distance (in feet)
t = time
V = velocity (in mph)
v = velocity (in feet per sec.)
v_0 = initial or beginning velocity
vi = change of velocity
w = weight
x = horizontal distance (in inches)
y = vertical distance (in inches)
θ = angle (in degrees)

BASIC PHYSICS FORMULAS

Velocity = acceleration times time. So:

a. $v = at$ b. $t = \frac{v}{a}$ c. $a = \frac{v}{t}$

Distance = velocity times time. So:

d. $s = vt$ e. $t = \frac{s}{v}$ f. $v = \frac{s}{t}$

Where initial velocity (v_0) is changed ($\pm$ a):

g. $s = v_0t \pm \frac{at^2}{2}$ When v_0 is 0: $s = \frac{at^2}{2}$

h. Work = Force times distance = sF

i. $KE = \frac{Mv^2}{2} = \frac{wv^2}{2g}$ j. $F = Ma = \frac{wa}{g}$

k. Force of friction = fw

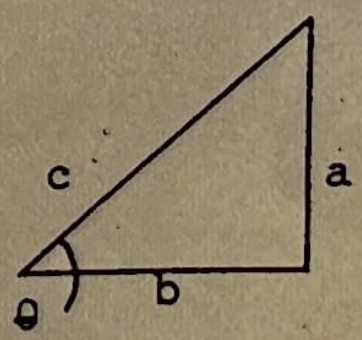
TRIGONOMETRIC FUNCTIONS

l. $c^2 = a^2 + b^2$

m. $\frac{a}{c} = \sin\theta$; $a = c\sin\theta$

n. $\frac{b}{c} = \cos\theta$; $b = c\cos\theta$

o. $\frac{a}{b} = \tan\theta = \frac{\sin\theta}{\cos\theta} = e$



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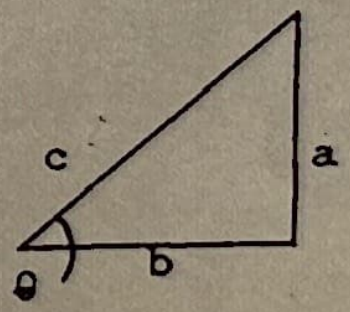
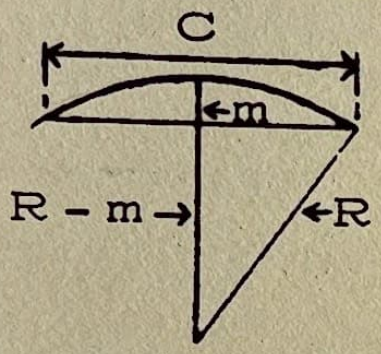


RADIUS FORMULA

From formula 1 page 7: $c^2 = a^2 + b^2$



$c = R$

$a = R - m$

$b = \frac{C}{2}$

$$R^2 = (R - m)^2 + (\frac{C}{2})^2$$

$$R^2 = R^2 - 2mR + m^2 + (\frac{C}{2})^2$$

$$R^2 - R^2 + 2mR = m^2 + \frac{C^2}{4} = \frac{C^2 + 4m^2}{4}$$

$$2mR = \frac{C^2 + 4m^2}{4} \qquad R = \frac{C^2 + 4m^2}{8m}$$

$$R = \frac{C^2}{8m} + \frac{4m^2}{8m} \qquad R = \frac{C^2}{8m} + \frac{m}{2}$$

SPEED DETERMINATION FORMULAS

#1. BASIC SKID FORMULA:

1. Level road: $V = \sqrt{30sf}$

2. On grade: $V = \sqrt{30s(f \pm e)}$

(derivation on page 11)

#2. CENTRIFUGAL SKID FORMULAS:

1. RADIUS: $R = \frac{C^2}{8m} + \frac{m}{2}$

2. Level road: $V = \sqrt{15Rf}$

3. On grade: $V = \sqrt{15R(f \pm e)}$

(derivation on pages 8 and 13)

#3. COMBINED SPEED FORMULA:

(for skids on different surfaces, speeds consumed in collision, falls etc.)

$$V^2 = V_1^2 + V_2^2 + V_3^2 + \cdots + V_n^2 \quad \text{or;}$$

$$V^2 = 30s_1f_1 + 30s_2f_2 + 30s_3f_3 + \cdots + 30s_nf_n$$

(derivation on page 16)

#4. MAXIMUM ACCELERATION

$$V = \sqrt{15s(f \pm e)} \qquad s = \frac{V^2}{15f}$$

(derivation on page 17)

SPEED DETERMINATION FORMULAS

#5. FALL FORMULAS

Take off on level:
(h = distance fallen in feet)

$$V = \frac{2.73s}{\sqrt{h}}$$

Take off on slope:

1. Landing at or above level of take off:

$$V = \frac{2.73s}{\cos\theta \sqrt{\tan\theta - h}}$$

2. Landing at or below level of take off:

$$V = \frac{2.73s}{\cos\theta \sqrt{\tan\theta + h}}$$

(derivation on page 18)

#6. VAULT FORMULA:

(vehicle leaps barrier at unknown angle)

1. Landing at or above level of take off:

$$V = \frac{3.9s}{\sqrt{s - h}}$$

2. Landing at or below level of take off:

$$V = \frac{3.9s}{\sqrt{s + h}}$$

(derivation on page 21)

#7. ROLL OVER SPEED

$$V = 1.57 \sqrt{\sqrt{x^2 + y^2} - y}$$

(derivation on page 21)

DERIVATION OF BASIC SKID FORMULA

To determine speeds from skids, we need to know certain facts which are found in many college physics books or dictionaries. Energy is measured in terms of how much work it can do. Work is done when an object is moved and is equal to the force required times distance moved. The resistance between the road and the tires of a vehicle is the force of friction and is equal to the force required to push a vehicle (locked wheels). The force of friction divided by the weight equals the co-efficient of friction. Force of friction equals the co-efficient of friction times weight (fw). The work done by a sliding vehicle is equal to the force of friction times distance slid (sfw). The vehicle had at least enough energy to do that amount of work. The energy possessed by a vehicle is KE, so KE must equal sfw.

A 4000# vehicle slid 50'. It is found that it requires a 2000# force to slide this vehicle on this road. Force of friction = 2000#.

Co-efficient of friction = $\frac{2000}{4000}$ = 50%

Work done = sfw = 50' times 50% times 4000#

$KE = \frac{wv^2}{2g} = sfw$; $wv^2 = 2gsfw$; $v^2 = \frac{2gsfw}{w}$

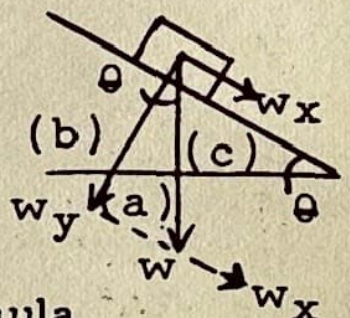
$v^2 = 2gsf$; Convert to mph:

$V^2 = (0.6818)^2(64.4)sf = 30sf$

DERIVATION OF BASIC SKID FORMULA

On grade:
The weight of a vehicle on a grade divides into two parts. One part (w_x) pulls downhill, the other (w_y) pulls down at right angles to the slope. W_y is the only portion of the vehicle's weight that comprises KE and force of friction. W_x pulls the vehicle downhill and either increases or decreases the amount of work that must be done to bring vehicle to a stop. A vehicle going uphill will stop quicker than one on the level at the same speed.

Knowing value of f on the level we can compute force of friction (fw) on a grade. The work done is = $sfw_y \pm sw_x$ (w_x is considered only during distance of slide).



From formula m & n page 7;
w is side (c), w_x is side (a), w_y is side (b) and we then have $w_x = w\sin\theta$ and $w_y = w\cos\theta$. We may now substitute these values in our formula from page 11.

$$KE = \frac{w\cos\theta v^2}{2g} = \text{work} = sfw\cos\theta \pm sw\sin\theta;$$

$$v^2 = \frac{2gs(f\cancel{w}\cancel{\cos\theta}s\cancel{\theta})}{\cancel{w}\cancel{\cos\theta}s\cancel{\theta}} \pm \frac{2g(s\cancel{w}\sin\theta)}{\cancel{w}\cos\theta} =$$

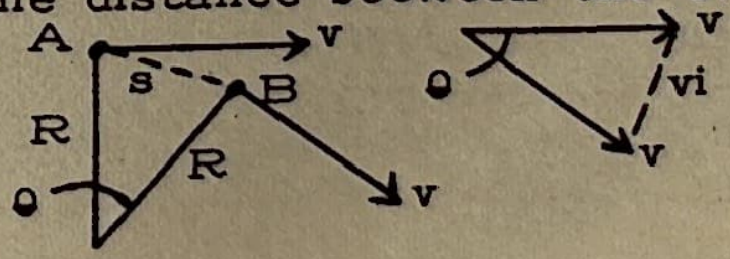
$$v^2 = 2gs(f \pm \frac{\sin\theta}{\cos\theta}) = 2gs(f \pm \tan\theta)$$

$$v^2 = 2gs(f \pm e) \qquad V^2 = 30s(f \pm e)$$

CENTRIFUGAL SKID FORMULAS

Tie a string to a rock and spin it in a circle. Three forces are acting on the rock; gravity, the string and centrifugal force. The string is pulling the rock to the center of the circle with an amount (centripetal force) dependent on size of the rock, length of string (R) and speed of travel. Centrifugal force is exactly opposite to centripetal force and pulls away from center. The rock is always traveling in a direction at right angles to the string. If centrifugal force becomes greater than centripetal force (string breaks), the rock will fly off in its direction of travel as of that moment.

If A and B are points on path of the rock, and are so close together that the path is a straight line, we see that the rock has a velocity in one direction at A and in a different direction at B. We can see that the angle between the two positions of v is the same as the angle between the two positions of R because the angle between v and R remains at 90° during all positions of rotation. Side vi is the difference between the two positions of v. Side s is the distance between the two points A and B.



CENTRIFUGAL SKID FORMULAS

We can establish a ratio between these two triangles. Since angle θ is the same size for each triangle:

$\frac{s}{R} = \frac{vi}{v}$ or: $sv = viR$. Now if we divide by time (t): $\frac{sv}{t} = \frac{viR}{t}$. From formula c page 7, we substitute for $\frac{vi}{t}$ (remember that vi was a velocity from page 13 and would be equal to at): $\frac{sv}{t} = aR$. Now if we substitute from formula f page 7:

$(v)(v) = aR$ or $v^2 = aR$ and: $a = \frac{v^2}{R}$

From formula j page 7: Force $= \frac{wa}{g}$; substitute a from above: Force $= \frac{wv^2}{gR}$

When a vehicle is rounding a curve, the same forces are present as with the rock on the string except that in place of the string to supply centripetal force, we must rely on the force of friction between the tires and the road. If centrifugal force becomes greater than the force of friction (fw) the vehicle will slide off the curve. Since we can determine the force of friction, we can let Force

CENTRIFUGAL SKID FORMULAS

equal force of friction: $\frac{wv^2}{gR} = fw$

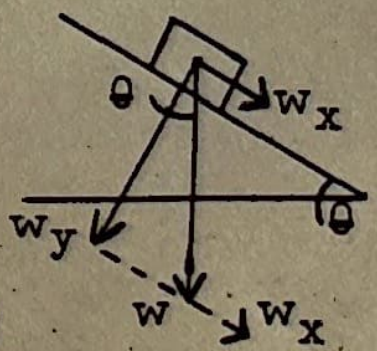
$wv^2 = gRfw$ $\qquad v^2 = \frac{gRfw}{w}$ $\qquad v^2 = gfR$

$V^2 = (0.6818)^2(32.2)fR$ $\qquad V^2 = 15fR$

On banked curve:
The weight (pull of gravity) divides into two parts just as it did on page 12. Centrifugal and centripetal forces act at right angles to gravity. On a positive banked curve, centrifugal force must be great enough to push the vehicle uphill, and on a negative banked curve w_x is aiding to pull it downhill. W_y is the only portion of the weight that comprises centrifugal and centripetal forces.

$$\frac{w_y v^2}{gR} = fw_y \pm w_x$$

$$\frac{w\cos\theta v^2}{gR} = fw\cos\theta \pm w\sin\theta$$



$$w\cos\theta v^2 = gR(fw\cos\theta \pm w\sin\theta)$$

$$v^2 = \frac{gR(fw\cos\theta \pm w\sin\theta)}{w\cos\theta} = gR(f \pm \frac{\sin\theta}{\cos\theta})$$

$$v^2 = gR(f \pm e)$$

$$V^2 = (0.6818)^2(32.2)R(f \pm e) = 15R(f \pm e)$$

COMBINED SPEED FORMULA

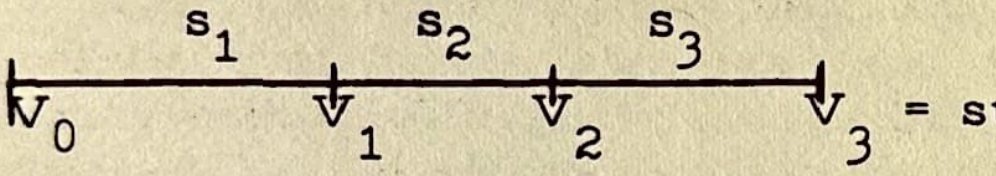
We know that the minimum speed of a vehicle can be determined from the formula:

$V^2 = 30fs$. Now let us consider(s) individually.

Let $s_1 + s_2 + s_3 = s$. Let V_0 = initial speed;

V_1 = speed at end of s_1; V_2 = speed at end

of s_2 and V_3 = speed at end of $s_3 = 0$.



$V_2^2 = 30fs_3$; $V_1^2 = 30fs_2 + 30fs_3$ and:

$V_0^2 = 30fs_1 + 30fs_2 + 30fs_3$.

If co-efficient of friction is different for each skid, we merely need to insert the value for each f and we obtain a true (minimum) value for V_0.

Since each formula of 30fs is equal to a V we can rewrite the above formula:

$V_0^2 = V_1^2 + V_2^2 + V_3^2 + V_n^2$ (any number)

MAXIMUM ACCELERATION

Four wheeled vehicles have about 1/4 of their weight on each wheel under normal conditions. When the vehicle is sliding we consider all four wheels pushing their weight against the force of friction. When the vehicle is accelerating only the two drive wheels are pushing. Force of friction under acceleration then is only 1/2 of what it is under de-celeration (sliding), or $\frac{fw}{2}$. Since a vehicle can accelerate only in proportion to the force it can exert on the road, the maximum amount of force possible is equal to the force of friction (if a greater force is applied, the tires will spin). We can determine the maximum amount of acceleration possible by letting Force = force of friction.

Force = $\frac{wa}{g} = \frac{fw}{2}$; $wa = \frac{gfw}{2}$; $a = \frac{gfw}{2w}$

From formula g page 7 ($v_0 = 0$): $s = \frac{at^2}{2}$

From formula b page 7: $t = \frac{v}{a}$ so:

$t^2 = \frac{v^2}{a^2}$; substitute t^2 in formula g: $s = \frac{av^2}{2a^2}$

$s = \frac{v^2}{2a}$; From a above $2a = gf$, substitute:

$s = \frac{v^2}{gf}$. Convert to mph: $s = \frac{V^2}{(0.6818)^2 gf}$

DERIVATION FALL SPEED FORMULA

When a vehicle runs off a bank so that it is in a free fall condition it is being acted on by gravity (g). When we examine the action of the velocity of the vehicle we can determine the relation between the time required to fall a certain distance and the speed necessary to traverse a certain horizontal distance in that period of time. The horizontal distance is obtained from formula d page 7: $s = vt$, the time required (formula e): $t = \frac{s}{v}$.

During this time (t) the vehicle will fall a certain distance (h). From formula g page 7 where v_0 = zero (falling speed): $s = \frac{at^2}{2}$.

Note that h = s and a = g: $h = \frac{gt^2}{2}$.

From our value for t above: $h = \frac{gs^2}{2v^2}$.

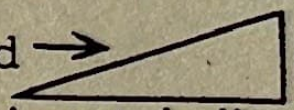
Transpose: $2v^2h = gs^2$, and again: $v^2 = \frac{gs^2}{2h}$.

Insert value for g: $v^2 = \frac{32.2s^2}{2h} = \frac{16.1s^2}{h}$.

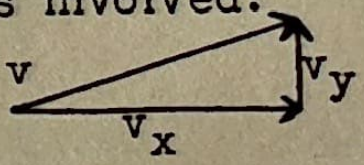
Find square root: $v = \frac{4s}{\sqrt{h}}$

Convert to mph: $V = \frac{(0.6818)(4)s}{\sqrt{h}} = \frac{2.73s}{\sqrt{h}}$

When a vehicle travels uphill its velocity has two components, the horizontal velocity (v_x) and the vertical velocity (v_y). The horizontal velocity relates to the amount of horizontal distance the vehicle is traversing in a given time (t) and the vertical velocity relates to the amount of vertical distance the vehicle is traversing in that same period of time. Since the time (t) is the same for each of these velocities we can study the relation between these velocities and the distances traversed:



Note that we have a triangle of the distances traversed and that we may also construct a similar triangle of the velocities involved:



From formulas m & n page 7:
We may solve for values of the sides of this triangle in terms of the other sides and angle θ: $a = v_y$; $b = v_x$; $c = v$; so:

$v_x = v\cos\theta$; $v_y = v\sin\theta$. Substituting these values into our formulas from page 18:
The time required to traverse the horizontal distance;

$(t = \frac{s}{v})$ becomes: $t = \frac{s}{v\cos\theta}$.

To determine vertical distance traveled, use formula g page 7 where v_0 is the initial upward velocity v_y and $a = g$ (which is negative)

Vertical distance = $h = v_y t - \frac{gt^2}{2}$.

Substitute for v_y and t (from page 19):

$$h = v\sin\theta \frac{s}{v\cos\theta} - \frac{gs^2}{2(v\cos\theta)^2}$$

$$h = \frac{\not{v}\sin\theta s}{\not{v}\cos\theta} - \frac{gs^2}{2(v\cos\theta)^2} = \tan\theta s - \frac{gs^2}{2(v\cos\theta)^2}.$$

Insert value for g: $h = s\tan\theta - \frac{32.2s^2}{2(v\cos\theta)^2}$.

Transpose: $h - s\tan\theta = -\frac{16.1s^2}{(v\cos\theta)^2}$.

Transpose again: $s\tan\theta - h = \frac{16.1s^2}{(v\cos\theta)^2}$.

Again: $(s\tan\theta - h)(v\cos\theta)^2 = 16.1s^2$,

and: $(v\cos\theta)^2 = \frac{16.1s^2}{s\tan\theta - h}$.

Take square root: $v\cos\theta = \frac{4s}{\sqrt{s\tan\theta - h}}$.

Transpose: $v = \frac{4s}{\cos\theta\sqrt{s\tan\theta - h}}$; convert:

$$V = \frac{(0.6818)(4s)}{\cos\theta\sqrt{s\tan\theta - h}} = \frac{2.73s}{\cos\theta\sqrt{s\tan\theta - h}}.$$

When the vehicle takes off from a downward slope gravity subtracts from initial velocity

and h becomes negative since it is below level of take off. Our formula becomes:

$$V = \frac{2.73s}{\cos\theta \sqrt{-h - \tan\theta}}.$$ This is the same as: $$V = \frac{2.73s}{\cos\theta \sqrt{\tan\theta + h}}$$

VAULT FORMULAS

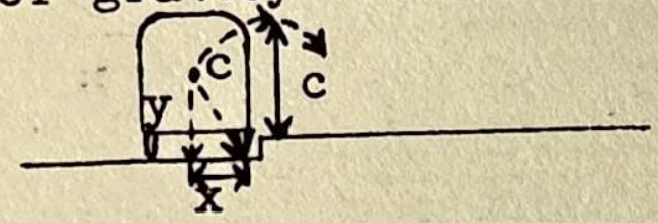
These formulas are the fall formulas on pages 20 & 21. These formulas assume a take off angle of 45° in as much as we do not know the angle at which the vehicle left the road. We can assume the angle to be 45° because if the vehicle took off at any other angle it would have had to be going faster to travel the same distance (s).

SPEED FROM ROLL-OVER

When a vehicle slides sideways into a curb or other obstacle and turns onto its side, it is possible to determine the minimum amount of work that is done. The amount of work that is done (from formula h page 7):

Work = sw, where s is distance the weight of the vehicle is lifted. For the purposes of measurements of this type, the weight of a vehicle is considered to be at the center of gravity.

Note the triangle. Side c is measured from center of gravity to outside edge of rim. As the vehicle rolls side c is the maximum height center of gravity will be lifted.



From formula 1 page 7, we find height lifted is: $s = \sqrt{x^2 + y^2} - y.$

To do this much work the vehicle must have possessed this much Kinetic Energy. So:

$$\frac{wv^2}{2g} = w(\sqrt{x^2 + y^2} - y)$$

$$v^2 = 2g(\sqrt{x^2 + y^2} - y).$$

Since g is in feet and x and y are in inches, we must convert:

$$v^2 = \frac{2g}{12}(\sqrt{x^2 + y^2} - y).$$

Convert to mph:

$$V^2 = \frac{(0.6818)^2(64.4)}{12}(\sqrt{x^2 + y^2} - y)$$

$$V^2 = 2.494(\sqrt{x^2 + y^2} - y)$$

$$V = 1.57\sqrt{\sqrt{x^2 + y^2} - y}$$

TABLE OF TANGENTS, COSINES, AND SINES

Angle	Tangent $\left(\frac{opp.}{adj.}\right)$	Cosine $\left(\frac{adj.}{hyp.}\right)$	Sine $\left(\frac{opp.}{hyp.}\right)$	Angle	Tangent $\left(\frac{opp.}{adj.}\right)$	Cosine $\left(\frac{adj.}{hyp.}\right)$	Sine $\left(\frac{opp.}{hyp.}\right)$
0°	.0000	1.0000	.0000	45°	1.0000	.7071	.7071
1	.0175	.9998	.0175	46	1.0355	.6947	.7193
2	.0349	.9994	.0349	47	1.0724	.6820	.7314
3	.0524	.9986	.0523	48	1.1106	.6691	.7431
4	.0699	.9976	.0698	49	1.1504	.6561	.7547
5	.0875	.9962	.0872	50	1.1918	.6428	.7660
6	.1051	.9945	.1045	51	1.2349	.6293	.7771
7	.1228	.9925	.1219	52	1.2799	.6157	.7880
8	.1405	.9903	.1392	53	1.3270	.6018	.7986
9	.1584	.9877	.1564	54	1.3764	.5878	.8090
10	.1763	.9848	.1736	55	1.4281	.5736	.8192
11	.1944	.9816	.1908	56	1.4826	.5592	.8290
12	.2126	.9781	.2079	57	1.5399	.5446	.8387
13	.2309	.9744	.2250	58	1.6003	.5299	.8480
14	.2493	.9703	.2419	59	1.6643	.5150	.8572
15	.2679	.9659	.2588	60	1.7321	.5000	.8660
16	.2867	.9613	.2756	61	1.8040	.4848	.8746
17	.3057	.9563	.2924	62	1.8807	.4695	.8829
18	.3249	.9511	.3090	63	1.9626	.4540	.8910
19	.3443	.9455	.3256	64	2.0503	.4384	.8988
20	.3640	.9397	.3420	65	2.1445	.4226	.9063
21	.3839	.9336	.3584	66	2.2460	.4067	.9135
22	.4040	.9272	.3746	67	2.3559	.3907	.9205
23	.4245	.9205	.3907	68	2.4751	.3746	.9272
24	.4452	.9135	.4067	69	2.6051	.3584	.9336
25	.4663	.9063	.4226	70	2.7475	.3420	.9397
26	.4877	.8988	.4384	71	2.9042	.3256	.9455
27	.5095	.8910	.4540	72	3.0777	.3090	.9511
28	.5317	.8829	.4695	73	3.2709	.2924	.9563
29	.5543	.8746	.4848	74	3.4874	.2756	.9613
30	.5774	.8660	.5000	75	3.7321	.2588	.9659
31	.6009	.8572	.5150	76	4.0108	.2419	.9703
32	.6249	.8480	.5299	77	4.3315	.2250	.9744
33	.6494	.8387	.5446	78	4.7046	.2079	.9781
34	.6745	.8290	.5592	79	5.1446	.1908	.9816
35	.7002	.8192	.5736	80	5.6713	.1736	.9848
36	.7265	.8090	.5878	81	6.3138	.1564	.9877
37	.7536	.7986	.6018	82	7.1154	.1392	.9903
38	.7813	.7880	.6157	83	8.1443	.1219	.9925
39	.8098	.7771	.6293	84	9.5144	.1045	.9945
40	.8391	.7660	.6428	85	11.4301	.0872	.9962
41	.8693	.7547	.6561	86	14.3007	.0698	.9976
42	.9004	.7431	.6691	87	19.0811	.0523	.9986
43	.9325	.7314	.6820	88	28.6363	.0349	.9994
44	.9657	.7193	.6947	89	57.2900	.0175	.9998
45	1.0000	.7071	.7071	90		.0000	1.0000

TO FIND CO-EFFICIENT OF FRICTION

Make a test skid at a known speed and insert the known values (speed and distance slid) in the formula:

$$f = \frac{V^2}{30s}$$

TABLE I

CONVERSION FACTORS

MULTIPLY	BY	TO OBTAIN
Feet per second	0.6818	Miles per hour
Miles per hour	1.467	Feet per second
Knots	1.689 1.853 1.152	Feet per second Kilometers/hour Miles per hour
Kilometers	0.9113 0.5396 0.6214	Feet per second Knots Miles per hour
Meters	3.281 39.37	Feet Inches
Kilos	2.2	Pounds

TABLE II

MINIMUM CENTRIFUGAL SKID-SPEED

Median (in inches)	C = 25 feet MPH		C = 50 feet MPH		C = 100 feet MPH	
	60%	70%	60%	70%	60%	70%
4"	45	49	91	98	*	*
5"	41	44	82	88	*	*
6"	37	40	75	80	*	*
7"	34	37	69	75	*	*
8"	32	35	65	70	130	140
9"	30	33	61	66	120	130
10"	29	31	58	62	115	125
11"	27	29	55	59	110	119
12"	26	28	53	57	105	114
14"	24	26	49	53	98	106
16"	23	25	46	50	91	99
18"	21	23	43	46	86	93
20"	20	22	41	44	82	88
22"	19	21	39	42	78	84
24"	18	20	37	40	75	80
26"	*	*	36	39	72	77
28"	*	*	34	37	69	74
30"	*	*	33	36	67	72
32"	*	*	32	35	65	70
36"	*	*	30	33	61	67
40"	*	*	29	31	58	62
50"	*	*	26	28	52	56
60"	*	*	24	26	47	51
70"	*	*	22	24	44	47
80"	*	*	21	22	41	44

TABLE III
SKID SPEEDS

(see formula #1 and page 11)
Read MPH in proper square

f	distance s																
	20	30	40	50	60	70	80	100	110	120	140	160	180	200	220	240	260	280
60%	18	23	26	30	32	35	37	42	44	46	50	53	56	60	62	65	68	70
70%	20	25	29	32	35	38	41	46	48	50	54	58	61	64	67	70	74	76

TABLE IV
REACTION DISTANCE
3/4 of a second
(normal time for drivers to react to danger)

distance	11	16.5	22	27.5	33	38.5	44	49.5
MPH	10	15	20	25	30	35	40	45
distance	55	60.5	66	71.5	77	82.5	88	93.5
MPH	50	55	60	65	70	75	80	85

TABLE V
Square root

number	root
25	5
100	10
225	15
400	20
625	25
900	30
1225	35
1600	40
2025	45
2500	50
3025	55
3600	60
4225	65
4900	70
5625	75
6400	80
7225	85
8100	90
9025	95

TABLE VI
FALL SPEED
Formula #5, take-off on level

h	horizontal distance s									
	10	20	30	40	50	60	70	80	90	100
2	19	38	58	77	96	*	*	*	*	*
5	12	24	36	48	60	73	85	97	*	*
10	8	17	25	34	43	51	60	69	77	86
15	*	14	21	28	35	42	49	56	63	70
20	*	12	18	24	30	36	42	48	54	61

h = elevation
s = horizontal distance

Measure elevation in feet.
Measure horizontal distance traveled in feet.
Read across table from elevation to square under the horizontal distance.
The figure in that square represents the speed in MPH required for a vehicle to have traversed an arc of those measurements.

TABLE VII

TABLE VIII

VAULT FORMULAS

(see page 21)

Read MPH in proper square

Landing at or below level of take-off:

h	horizontal distance s									
	10	20	30	40	50	60	70	80	90	100
0	12	17	21	24	27	30	32	34	36	39
2	11	16	20	24	27	29	32	34	36	38
5	10	15	19	23	26	29	31	33	36	38
10	*	14	18	22	25	27	30	32	35	37
15	*	13	17	21	24	27	29	32	34	36
20	*	12	16	20	23	26	28	31	33	35

Landing above level of take-off:

h	horizontal distance s									
	10	20	30	40	50	60	70	80	90	100
0	12	17	21	24	27	30	32	34	36	39
2	13	18	22	25	28	30	33	35	37	39
5	17	20	23	26	29	31	33	36	38	40
10	*	24	26	28	30	33	35	37	39	41
15	*	*	30	31	32	34	36	38	40	42
20	*	*	*	34	35	36	38	40	41	43